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ABSTRACT

A major difficulty in trying to improve the level of achievement in public schools in the United States is that there is little consensus on the nature of the causes or the solution to the current educational problems. The variety and range of proposed solutions have grown as the inability of schools to restore science achievement has become more evident. This research focuses on changes in four of the variables related to science achievement: teachers, students, curricula, and school grades. The research examines: (1) meta-analyses of the effectiveness of the innovative science curricula on students' achievement; (2) research on changes in teacher and student characteristics between 1957 and 1990; (3) the educational literature on the changes in the goals of public education during this same period; and (4) changes in student achievement. The topics of teacher reforms, science textbooks, drop-out prevention programs, student standards, parental involvement, school accountability, schools of choice, year-round schools, and corporate partnerships are discussed. (KR)

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DECLINES IN SCIENCE ACHIEVEMENT: IMPLICATIONS FOR PUBLIC EDUCATION

By

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INTRODUCTION

Between 1959 and 1972, the National Science Foundation (NSF) allocated approximately two-thirds of its budget for the creation of innovative science curricula in grades 7 to 12 (Weinstein, Boulanger, & Walberg, 1982). The educational reforms led to new methods of instruction and major innovative science curricula that were introduced into public schools in the United States during the 1960s and 1970s.

During the 1980s, a national concern for declining student achievement led to nationwide educational reforms. Despite these reforms, national and international indicators of science and mathematics performance of students in the United States still showed little improvement (National Science Board, 1990).

Why is it that the innovative science curricula and instructional strategies, and other educational reforms have not resulted in gains in student achievement in science.

Clearly, there is no consensus on the nature of nor the solution to the current educational problems. For example, Tifft (1989) reported that the solution to the current educational problems is to increase funding dramatically and to improve science teaching methods. Some of the national educational reports (National Commission on Excellence in Education, 1983; National Science Board, 1983; U.S. Department of Education, 1983) concluded that teacher salaries are the key to student achievement.

Certain educational critics claim that the solution involves greater emphasis on teaching higher order thinking skills (Arter, 1987). Still others, such as United States Secretary of Energy James D. Watkins and American Federation of Teachers President Albert Shanker, argue that better curricula are needed (Tifft, 1989). In contrast, the report, *A Nation at Risk* (1983) cited teacher incompetencer. According to the report, half of the nation's science teachers were not qualified to teach their subjects. Altbach (1985) offers a very different explanation of the current crisis in

education. Altbach argues "Thus, the crisis in education is caused directly by social policy and public opinion." (p. 15)

The variety and range of proposed solutions have grown as the inability of schools to restore science achievement has become more evident. More modest reforms include longer school days, an increased school year, testing of students and teachers, and increased graduation requirements, which include more courses in mathematics and science. More extreme solutions include year-round schooling, magnet schools, and schools of choice, as well as proposals to completely restructure schools (Sizer, 1983; Chubb & Moe, 1990).

Teachers, administrators, parents, school boards, and state and federal governments all need to understand the causes for the current crisis in science education in order to find solutions (Kavale, 1988). Unless the factors responsible for declining science achievement are isolated, time, effort, and large amounts of money may be wasted trying to implement illusionary solutions. But more importantly, the nation is at a critical juncture, and the road taken into the next century will depend upon the quality of our science programs in public schools.

The premise of this research is that changes in curricula, teachers, students, or school goals must be related to the changes in student achievement after 1963. The research approach was to (a) analyze trends in student achievement in science between 1957 and 1990; (b) describe and evaluate the curricula changes during this period; (c) describe changes in teacher and student characteristics, changes in requirements for teachers and students, and changes in school goals that relate to changes in science achievement; and (d) relate changes in each of these factors to changes in student science achievement.

TRENDS IN SCIENCE ACHIEVEMENT

During the last two decades a series of national and international assessments of student achievement in science have been documented declining performance among U.S. students.

National Assessment for Educational Progress

The National Assessment for Educational Progress (NAEP) measured the science achievement of 13- and 17-year-old American students in 1970, 1973, 1977, 1982, and 1986. The result of this testing showed that student scores were lower in 1986 than in 1970. Furthermore, the improvement in scores during the 1980s occurred in the lower skill categories. Despite a decade of educational reforms that specifically emphasized higher order thinking skills, students were less able to analyze and to integrate scientific information in 1986 than in 1977.

International Tests of Science Achievement

The declines in student science achievement were not confined to the National Assessments of Educational Progress. Two international tests of science achievement were conducted in 1986 and 1988. The first assessment was *Science Achievement in Seventeen Countries*, conducted by the International Association for the Evaluation of Educational Achievement (IEA); the second assessment was *The International Assessment of Educational Progress* (IAEP), conducted by the Educational Testing Service. The IAEP tested 13-year-olds in six countries.

Science Achievement in Seventeen Countries. In this study, 14-year-old United States students were outscored by students in Hungary, Japan, Netherlands, Canada, Finland, Sweden, South Korea, Poland, Norway, Australia, England, and Italy. The students in the United States were tied with students in Singapore and Thailand. Only students in Hong Kong and the Philippines scored lower than students in the United States.

Achievement scores were also determined for grade 12 students who were taking biology, chemistry, or physics. In these tests, students in Hong Kong and the United Kingdom scored the highest. Students in the United States ranked last in biology, ahead only of Canada and Finland in chemistry, and fifth from last in physics.

International Assessment of Educational Progress (IAEP). In 1988, the IAEP conducted science and mathematics assessments in five countries and 4 Canadian provinces. The project evaluated 13-year-old students in the United States, Canada, Korea, the United Kingdom, Spain, and Ireland. According to IAEP tests, students in the United States were outscored by students in Korea, the United Kingdom, Canada, and Spain. Only students in Ireland scored lower than students in the United States in science proficiency.

Scholastic Aptitude Mathematics Test (SAT-M)

The scoring trends in SAT-M, which is strongly correlated with achievement in college science and engineering, have nearly paralleled the trends in the national and international tests of student science achievement. After 1963, the SAT-M scores followed a nearly unbroken pattern of decline, reaching a low point of 466 in 1981, with average SAT-M scores dropping nearly 40 points. From 1981 to 1985 the SAT-M scores climbed nine points. However, since 1985, the curve has been nearly flat with SAT-M scores increasing by only one point. In 1990 the aggregate SAT-M score of 476 was still 26 points lower than in 1963; 12 points lower than in 1970.

By 1990 following a decade of comprehensive, national educational reforms, the weakness of the gains in science achievement questioned the efficacy of these reforms. Education Secretary Lauro F. Cavazos reflected, "Today's college bound students are still scoring significantly below those of 20 years ago. This is especially disheartening at the end of a decade marked by substantial education reform efforts" (Dodge, 1989). (p. 8) The seriousness of the declines in student achievement in science was recognized in the 1989 edition of *Science Indicators*, which noted that, "Compared with students in other

developed countries, American students demonstrate lower achievement in problem solving and higher-order thinking. (p. 21)

The research is substantial and conclusive. Student achievement in science peaked in the early 1960s. The declines that followed are genuine and the weakness of the recovery during the 1980s is a fact.

META-ANALYSIS OF CURRICULA AND INSTRUCTIONAL EFFECTS

The effectiveness of the innovative science curricula developed during the last 30 years was evaluated, based on the review of meta-analyses by Becker (1989); Kavale (1988); Tamir (1985); Wilson, (1983); Kulik and Kulik (1982); and Weinstein, Boulanger, and Walberg (1982); as well as the Science Meta-analysis Project (1983). This project, a multi-institutional effort, was designed to "integrate the findings of extant research studies directed toward the major science education research questions" (Anderson, Kahl, Glass, & Smith, 1983). The results of this project were re-analyzed in 1987, using improved meta-analytic methods (Shymansky, Hedges, Woodworth, 1987).

Between 1959 and 1973, 19 innovative science curricula projects for grades 7 to 12 were funded at a cost of 92 million dollars by the National Science Foundation (Weinstein, Boulanger, & Walberg, 1982). These projects included both summer and full-year teacher institutes to train teachers to use the new curricula, and evaluation studies of the effectiveness of the innovative curricula compared to traditional curricula methods.

The most widely implemented secondary science curricula included Biological Science Curriculum Study (BSCS), CHEM Study, Introduction to Physical Science (IPS), Harvard Project Physics, and Physical Science Study Committee Physics (PSSC).

Weinstein, Boulanger, and Walberg (1982) analyzed 33 studies of innovative high school science programs that involved a total of 19,149 junior and senior high school students in the United States, Great

Britain, and Israel. They concluded that:

> the post-Sputnik (1958) curricula produced beneficial effects in science learning that extended across science subjects in secondary schools, types of students, various types of cognitive and affective outcomes, and experimental rigor of the research. (pp. 518-519)

The meta-analysis by Shymansky et al. (1983) included 105 studies of 27 different science curricula and 18 different student performance measures. The authors concluded that the average student in the new science curricula exceeded the performance of 63% of the students in traditional science courses. Shymansky et al. also found that the innovative curricula improved student attitudes toward science and student self concept; as well as critical thinking, problem solving and mathematics achievement.

The innovative curricula of the 1960s and 1970s were accompanied by numerous innovative instructional approaches. These instructional methods included advance organizers, cues and reinforcement, computer-based instruction, mastery learning, and personalized instruction. Other instructional changes included a de-emphasis of ability-grouping and the introduction of new audio-visual technology into schools, and smaller class sizes.

The body of research on the effectiveness of these innovative instructional approaches and instructional trends indicates that like the innovative science programs these changes should have improved student science achievement. All of these innovations and trends have been shown separately to have a positive effect on achievement.

TEACHER QUALIFICATIONS

Many of the educational reports released during the 1980s singled out teachers as a primary cause of the decline in student achievement in science. These reports were criticized by Rock et al. (1985) and Raywid, Tesconi, and Warren (1984) who pointed out that there was little available research that supported the claim that teacher quality had declined during the 1970s and 1980s.

In sharp contrast to the conclusions of the commission reports of the 1980s, the National Education Association (1976) had reported that teachers in the 1970s were better prepared than their predecessors. This assertion was supported by trends in teacher training. In 1961, for example, fully 15% of all teachers did not have a bachelor's degree. However, by 1976 this number had been reduced to 1%. The trend with master's degrees was similar. In 1961, 23% of the teachers held a master's degree. By 1965 the percentage had increased to 29.6% (*Digest of Education Statistics*, 1968), and by 1980 the percentage of teachers with a master's degree had increased to 31.6% (Rock et al., 1985). According to the 1986 Metropolitan Life Survey, principals (44%), superintendents (51%), and deans (60%) rated the overall quality of new teachers entering the profession as better than the quality of new teachers in the past.

The evidence clearly supports the contention that teachers were dedicated and qualified. Certainly, there seems to be scant evidence that could be used to make a case for a negative trend in teacher quality, which could be used to explain the declines in student achievement in science.

STUDENT CHARACTERISTICS

The relationship between student characteristics and achievement is well documented. Numerous studies have linked student achievement to socio-economic status, parental educational levels, racial or ethnic background, and attitude toward school (Applebee, 1989; Lapointe, 1989; Carnegie Foundation, 1990).

The Educational Testing Service (ETS) study of factors associated with declines in test scores of high school seniors (Rock et al., 1985) found that there were significant changes in high schools and in student behavior between 1972 and 1980. The ETS study found that throughout the 1970s, students became increasingly concerned with making money and less concerned with making social contributions.

Rock et al. (1985) concluded that shifts in population demographics played only a minor role in

declining test scores. Instead, they found that changes in student behaviors and school characteristics played major roles in score declines. Further, they concluded that student school behaviors were more important than school characteristics in the decline of the SAT-M score.

SCHOOL GOALS

Since 1957 the Federal Government has become increasingly active in using schools as vehicles to correct problems of national concern (Ravitch, 1983). As the Federal Government has shifted the focus of education, goals were changed for schools.

A second influence on school goals has been changes in the American society. The turmoil of the 1960s stripped away the last vestige of academic autonomy. The loss of academic autonomy made schools more vulnerable to changes in the winds of societal issues. A third influence on school goals, related to societal changes, is changes in the American family. The significant role that parents and students now play in the areas of curriculum and academic standards has presented schools with a new set of problems. Because the characteristics of parents and children have changed significantly in recent decades as the structure of the American family has radically changed, schools have been forced to accommodate the rapidly changing needs of parents and students. The dramatic changes in the SAT after 1963 can only be explained in relation to the equally dramatic changes in American society at this time.

DECLINES IN SCIENCE ACHIEVEMENT: A RIVAL HYPOTHESIS

The hypothesis that has been developed from this research is that (a) the recent declines in science achievement are most likely due to changes in student characteristics and motivation, (b) to changes in school goals, and (c) to changes in the school autonomy, which have caused schools to lose control over academic standards. The research suggests that changes in teachers or curricula should have resulted in gains in student achievement -- not declines.

If we assume that the declines in science achievement are related to changes in student motivation,

school goals, and school autonomy; then reforms that raise student motivation or that shift school goals in favor of more rigorous achievement standards should result in improvements in science achievement. Reforms aimed at improving science curricula should have much smaller positive effects on student achievement.

Teacher Reforms. In general, reforms aimed at improving teacher quality should have only minimal effects. One exception, however, is performance-based pay. If teacher salaries are tied to student achievement, then teachers will be encouraged to raise standards for student achievement. An interesting point about this reform is that the increases in student achievement will result not because of better teaching, but because higher standards are required. Schools could achieve the same effect without having to institute "merit pay" by simply establishing and enforcing school goals that demand higher achievement.

A second exception that should be expected to raise student achievement is teacher empowerment. If teachers were given the authority to set school standards for achievement and these standards were then supported by the administration and the school board, then dramatic improvements in student achievement could result. This particular reform, however, has not been widely implemented in schools, and teachers continue to be excluded from involvement in deciding policies for promotion and retention. Ernest Boyer, President of the Carnegie Foundation, in the foreword to the Carnegie Foundation report, *The Condition of Education* (1990) said, "When it comes to crucial decision making, teachers are often left out. . . they are not significantly involved in setting student promotion and retention policies at their school. I find it especially disturbing that teachers report a sharp decline in the control they feel they have over their professional lives. (p.v)

Science Textbooks. One curricular reform that should result in higher student science achievement, however, is the move to strengthen science textbooks. Because teachers rely to a great extent on the textbook, textbook quality has a great effect on the information that the student receives.

Because adoption states represent a sizable guaranteed income for publishers whose texts are adopted, these various forces can exert a great deal of pressure on publishers. Therefore, the likelihood of textbooks improving significantly in the next few years depends to a large extent on the societal factors that determine the thrust of the various state adoption committees.

Drop-out Prevention Programs. Can schools develop policies to keep at-risk students from dropping out and at the same time improve student achievement in science? There is not conceptual incongruity with these two educational goals. However, the conflict is at the policy level. By allowing students to pass courses and to proceed to the next grade without having mastered the material, schools send a clear message that high standards are not necessary to succeed. Furthermore, this policy communicates to the other students that minimal efforts are adequate to succeed.

Student Standards. Those reforms that raise student achievement levels required to get passing grades, to be promoted, or to graduate should result in higher student achievement. Therefore, the state reforms that raise course standards or graduation requirements should result in higher student achievement. Similarly, athletic or extracurricular policies that demand higher student achievement will also result in higher student achievement.

In much the same way, reforms that require student competency testing should lead to higher student achievement, if the passing scores indicate a meaningful level of achievement. By the end of 1988, 40 states had initiated minimum competency testing (Digest of Education Statistics, 1989 [p. 145]), and 19 states required students to pass a competency test to graduate from high school (*Education Indicators*, 1989 [p.68).

Parental Involvement. Virtually all of the recent educational reform reports call for greater involvement of parents in the education process. According to the Gallup Poll (1990), a majority of the general public believes that parents should have more control over the allocation of school funds and over the curriculum. More than 40% of the respondents believed that parents should also have a greater say in

the selection and hiring of teachers and administrators, as well as a greater voice in the selection of books and instructional materials.

Can we expect that parental control over funding, hiring of teachers, and curricula to improve student achievement? Probably not. Such involvement is more likely to have a very strong negative effect on student achievement. The reason why this type of parental involvement could have a negative influence is that it can serve to further weaken school autonomy in setting academic standards.

On the other hand, parental involvement can improve science achievement if the involvement involves supporting school goals, working with students to improve student motivation, or working to alter school goals in the direction of higher standards of achievement.

School Accountability. School accountability should have some slight positive effect on student achievement. The effect should only be slight because making schools accountable for student achievement without giving them autonomy needed to enforce high academic standards cannot be very effective. One way that schools might accommodate these requirements is to teach to the competency tests. In a number of school systems, teacher and principals have already been accused of altering student test answers or changing student scores. School accountability can have a very positive effect on achievement, but only if it is accompanied by increased autonomy in the area of academic standards.

Schools of Choice. Schools of choice allow parents and students to decide which school the students will attend. Referring to such schools, President Reagan said, "Choice works and it works with a vengeance" (Paulu, 1989). (p. 1) What schools of choice do offer are (a) greater autonomy for the school and (b) greater incentives for improved student motivation. The very fact that a student chooses a school makes the school special to that student, which gives the student a greater incentive to stay in school. Similarly, if the student does not meet the school requirements then the ability of the school to remove that student from its rolls provides the school with the autonomy needed to maintain academic goals and standards. It would seem that schools of choice can be very successful. On the other hand, traditional public schools

could achieve similar successes if their previous autonomy and commitment to student achievement were restored.

Year-round Schools. Another educational reform that should only have very small effects on achievement is increased school time. Longer school days or a longer school year, or both, will only keep students in school longer. Students now spend more time in school that at any other time in our nation's history. The amount time spent learning is not the problem. Simply keeping low motivated students in school will most likely have little effect on student achievement. It would be equally beneficial and much less expensive to simply have students learn more in less time. Again, this can be accomplished by increasing student motivation and demanding higher achievement levels.

Corporate Partnerships. Some of the proposed educational reforms have suggested forging ties between businesses and public schools. Such partnership might involve administrative training of school personnel. The partnerships could also be used to provide speakers, counselors, and advisory councils for schools, as well as summer jobs for students.

Corporate partnerships should raise student achievement, if the reforms concentrate on raising student motivation. Although as schools have already found out, it is not that easy to change student attitudes and characteristics. The level of success of such partnerships will depend upon the extent to which they improve student motivation and raise student achievement.

CONCLUSIONS

Teachers today know better how to teach than their predecessors three decades ago. The curriculm, methods of instruction, and educational technology far surpass what was available 30 years ago. And yet, by nearly every measure, American public schools are no longer as effective in teaching science as they were in the past. If the primary goal of public education was simply to raise science achievement, the educational solutions would be simple. The formula for high levels of science achievement are well; they are fairly simple and straight forward -- good teachers, strong curricula, high

standards for academic success, and motivated learners. The current crisis in science education is more closely related to changes in school goals, student motivation. The Roman historian, Livy, in his preface to *The History of Rome*, said, "...profecta ab exiguis initiis, crevrit eo ut jam laboret sua magnitudine[1]. This quote, which referred to the declining state of the Roman empire, might equally apply to the present state of public education in the United States.

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[1]having set out from small beginnings, it has increased to such an extent that it is now distressed by its own bulk

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